Plasmon mass in Yang-Mills theory

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Classical Yang-Mills theory (CYM)

We consider pure glue QCD, given by Lagrangian

$$\mathcal{L} = -\frac{1}{4} F^{\mu\nu,a} F^{a}_{\mu\nu}, \tag{1}$$

where $F^{\mu\nu} = \partial^{\mu} A^{\nu} - \partial^{\nu} A^{\mu} + ig\,[A^{\mu}, A^{\nu}]$ is the non-abelian field strength tensor.
Yang-Mills EOMS

$$[D^{\mu}, F_{\mu\nu}] = 0. \tag{2}$$

Solve these in temporal gauge on a 3d space lattice.

Gauge fixed observables

Quasiparticle picture of classical fields?

$$E = \frac{1}{2}\int \mathrm{d}^3x \left(E_i\left(x\right)^2 + B_i\left(x\right)^2\right) = 2\left(N_c^2 - 1\right) V \int \frac{\mathrm{d}^3k}{\left(2\pi\right)^3} kf\left(k\right)$$

gives

$$f\left(k\right) = \frac{1}{2}\frac{1}{2\left(N_c^2-1\right)}\frac{1}{V}\left(\left|k\right|\left|A_C\right|^2 + \frac{\left|E_C\right|^2}{\left|k\right|}\right) \tag{3}$$

We can also study the effective dispersion relation

$$\omega^2\left(k\right) = \frac{\left\langle\left|E_C\left(k\right)\right|^2\right\rangle}{\left\langle\left|A_C\left(k\right)\right|^2\right\rangle} \tag{4}$$

Plasmon mass

3 methods to determine the plasmon mass:

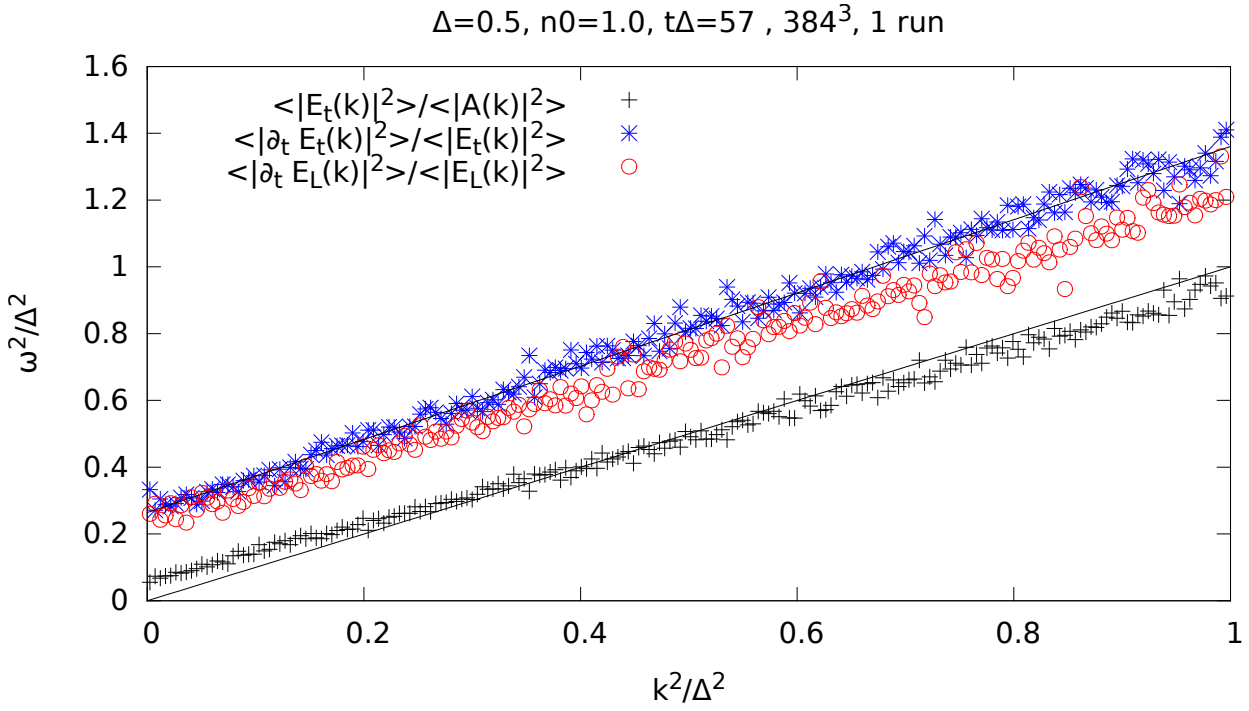
- Dispersion relation at zero momentum
- HTL:

$$\omega_{\mathrm{pl}}^2 = \frac{4}{3} g^2 N_c \int \frac{\mathrm{d}^3 k}{(2\pi)^3} \frac{f(k)}{|k|} \tag{5}$$

- Add uniform electric field, measure oscillations (UE).

Dispersion relation (3D)

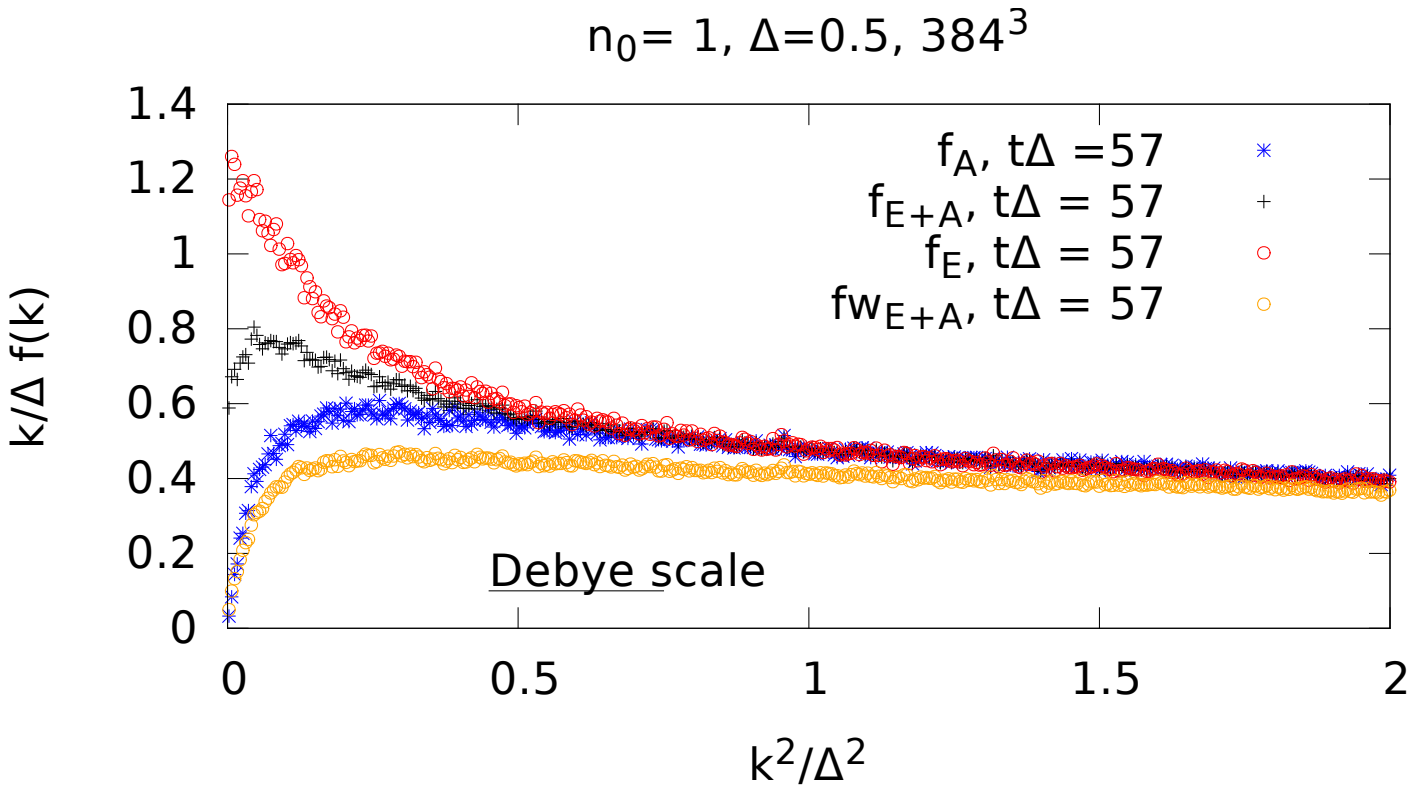
- We can also extract the dispersion relations of longitudinal and transverse plasmons separately.



- HTL $\omega^2/\Delta^2 \sim 0.2$, UE $\omega^2/\Delta^2 \sim 0.14$.

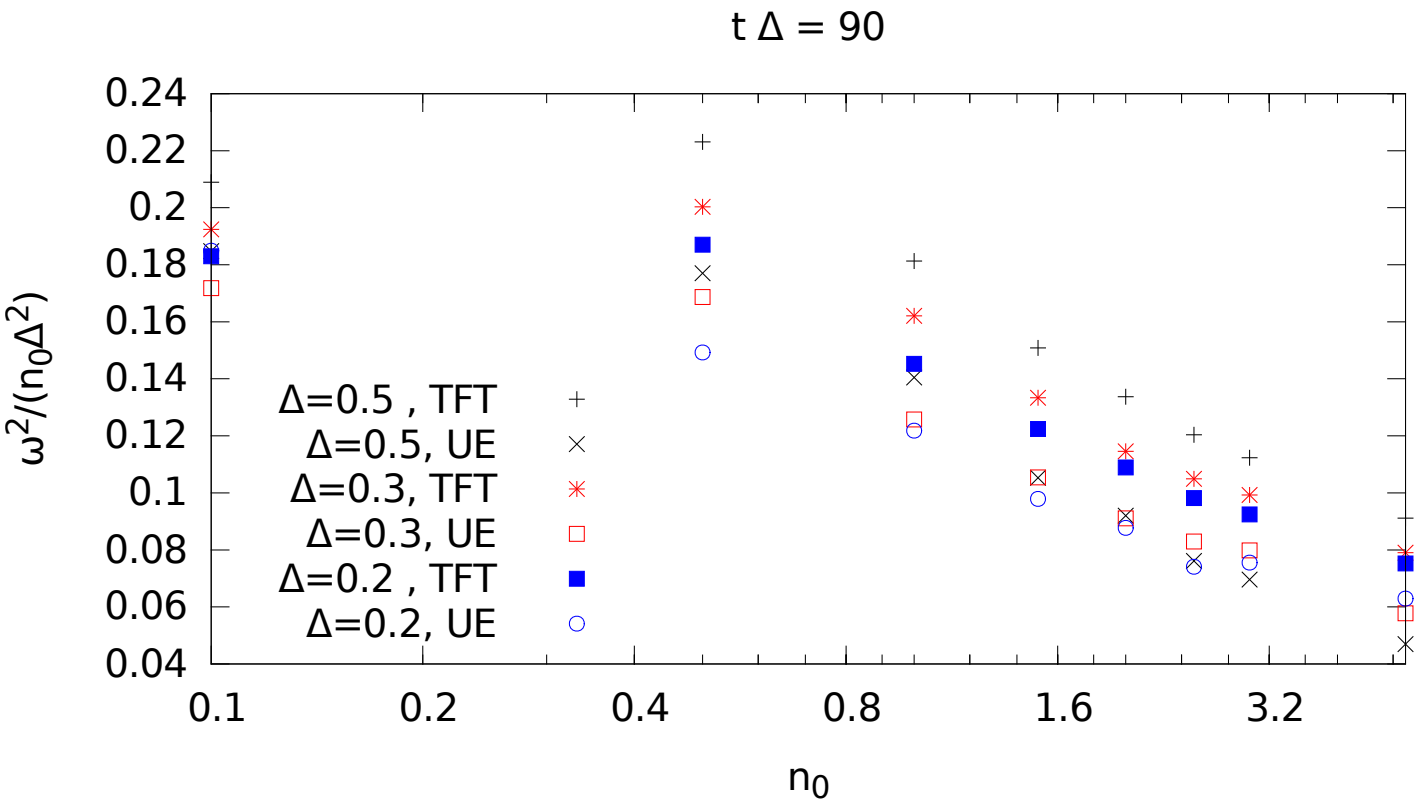
Occupation number distribution (3D)

- Sample initial gauge fields s.t. $f = n_0 \frac{k}{\Delta} \exp\left(-\frac{k^2}{2\Delta^2}\right)$.



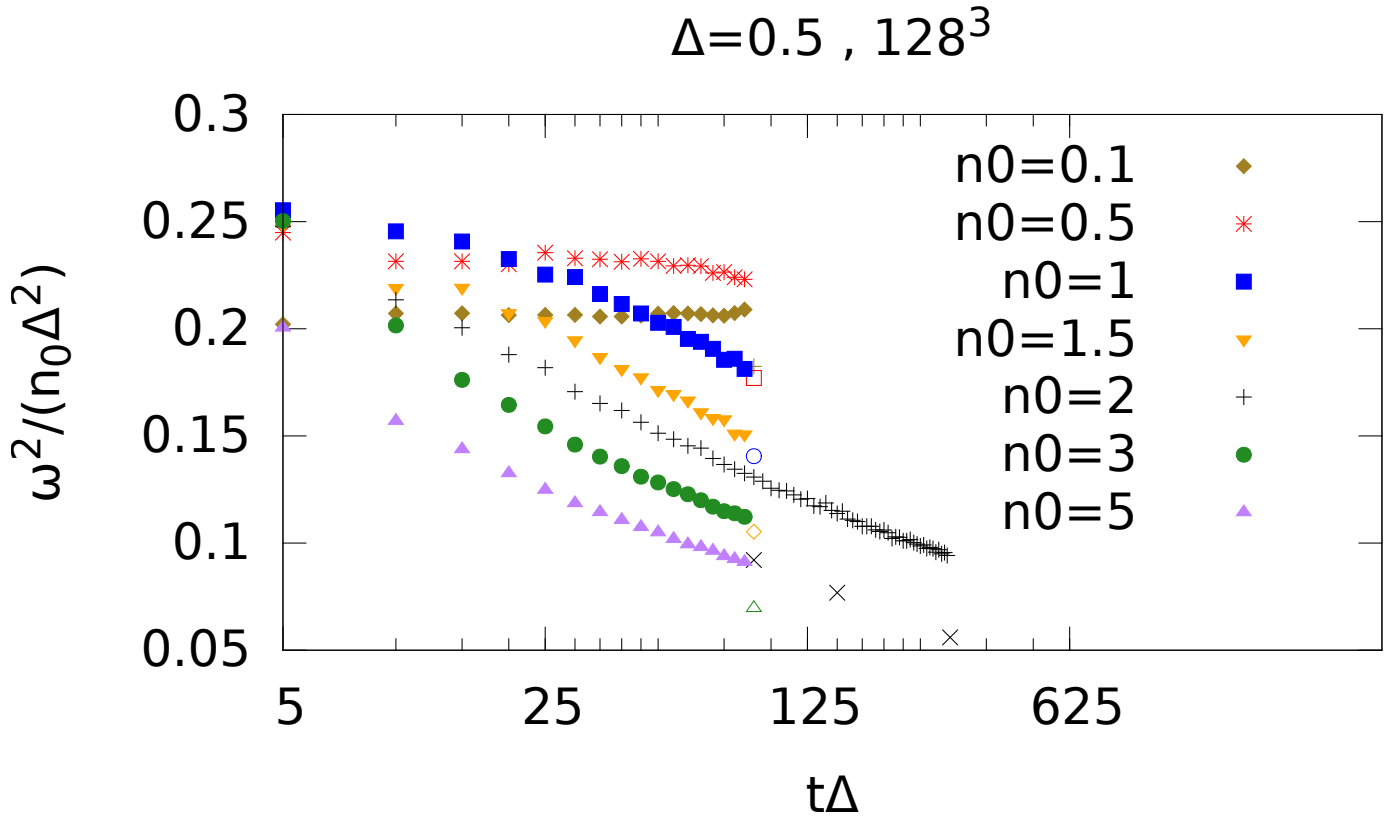
Occupation number dependence (3D)

Observe a difference between UE and HTL.



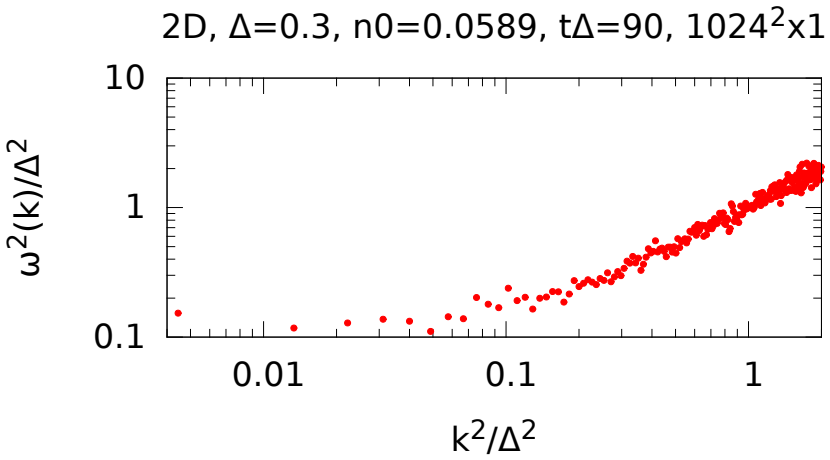
Time dependence (3D)

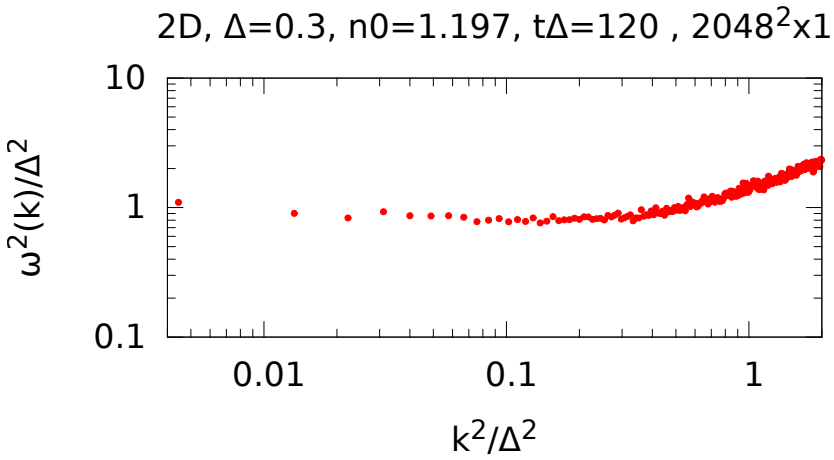
- Little time dependence for dilute system
- Decrease in mass scale for dense system



2D system

In 2D the agreement is much better



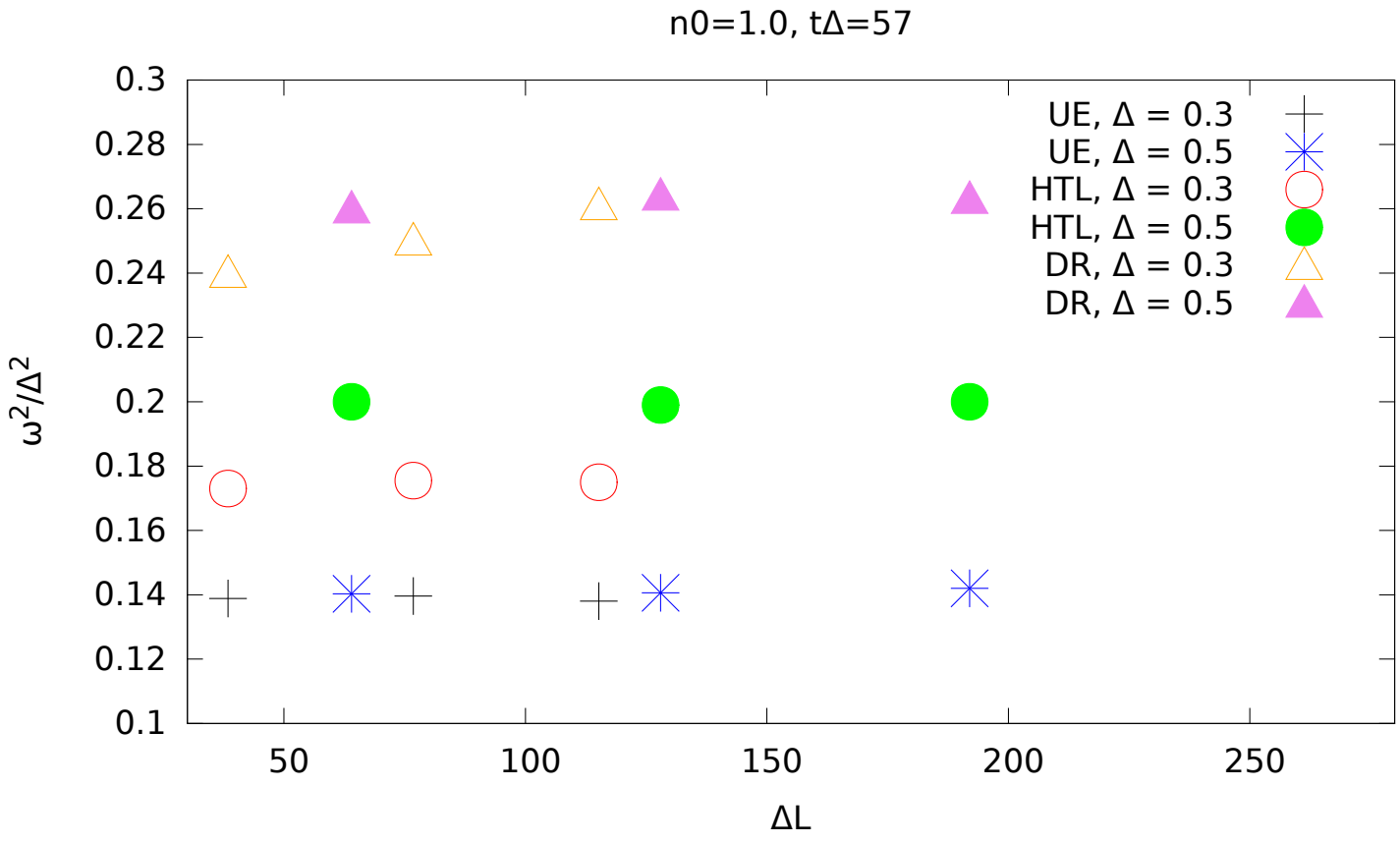


- HTL $\omega^2/\Delta^2 \approx 0.17$
- UE $\omega^2/\Delta^2 \approx 0.11.$

- TFT $\omega^2/\Delta^2 \approx 1.12$
- UE $\omega^2/\Delta^2 \approx 1.22$

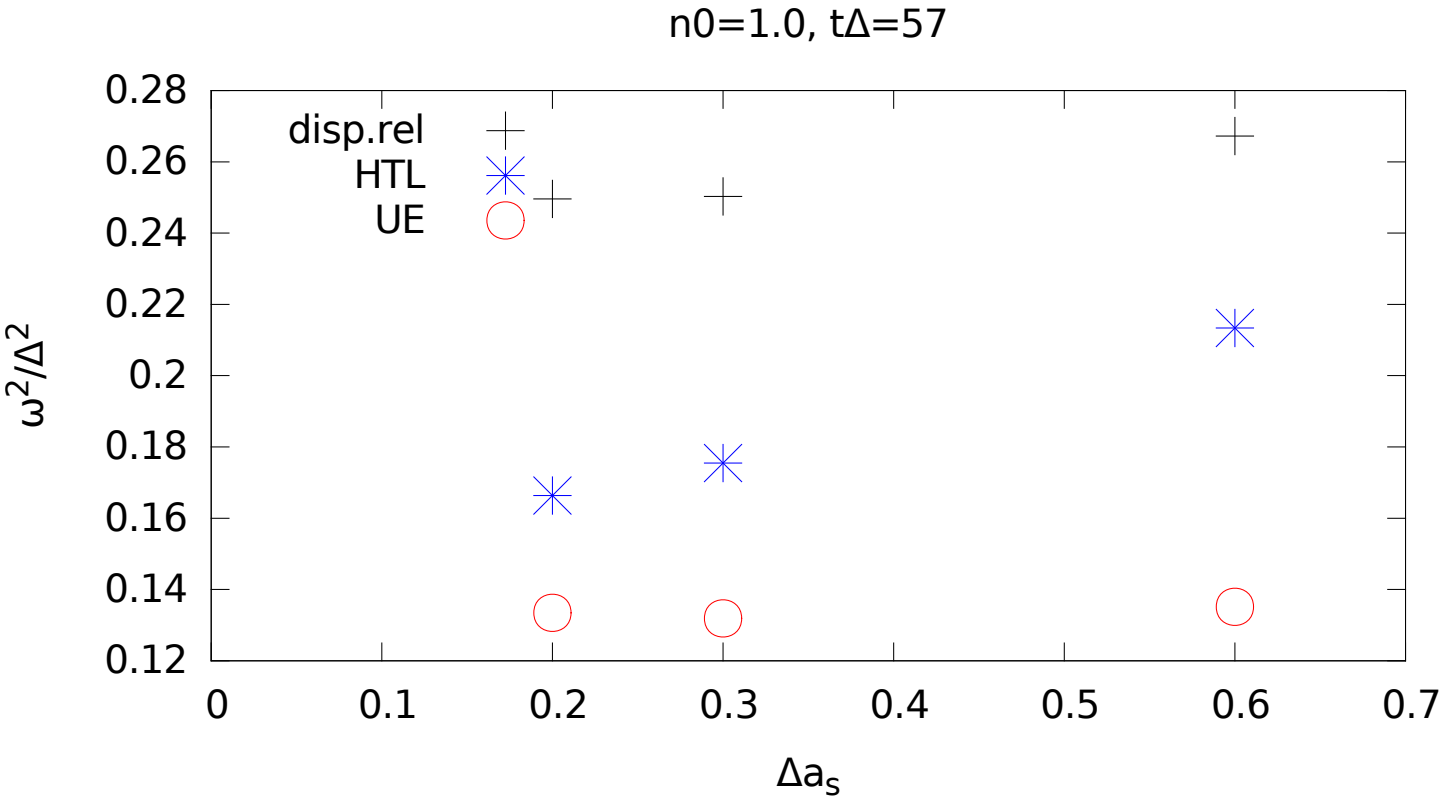
IR cut-off(3D)

- We find no IR cut-off dependence



UV cut-off(3D)

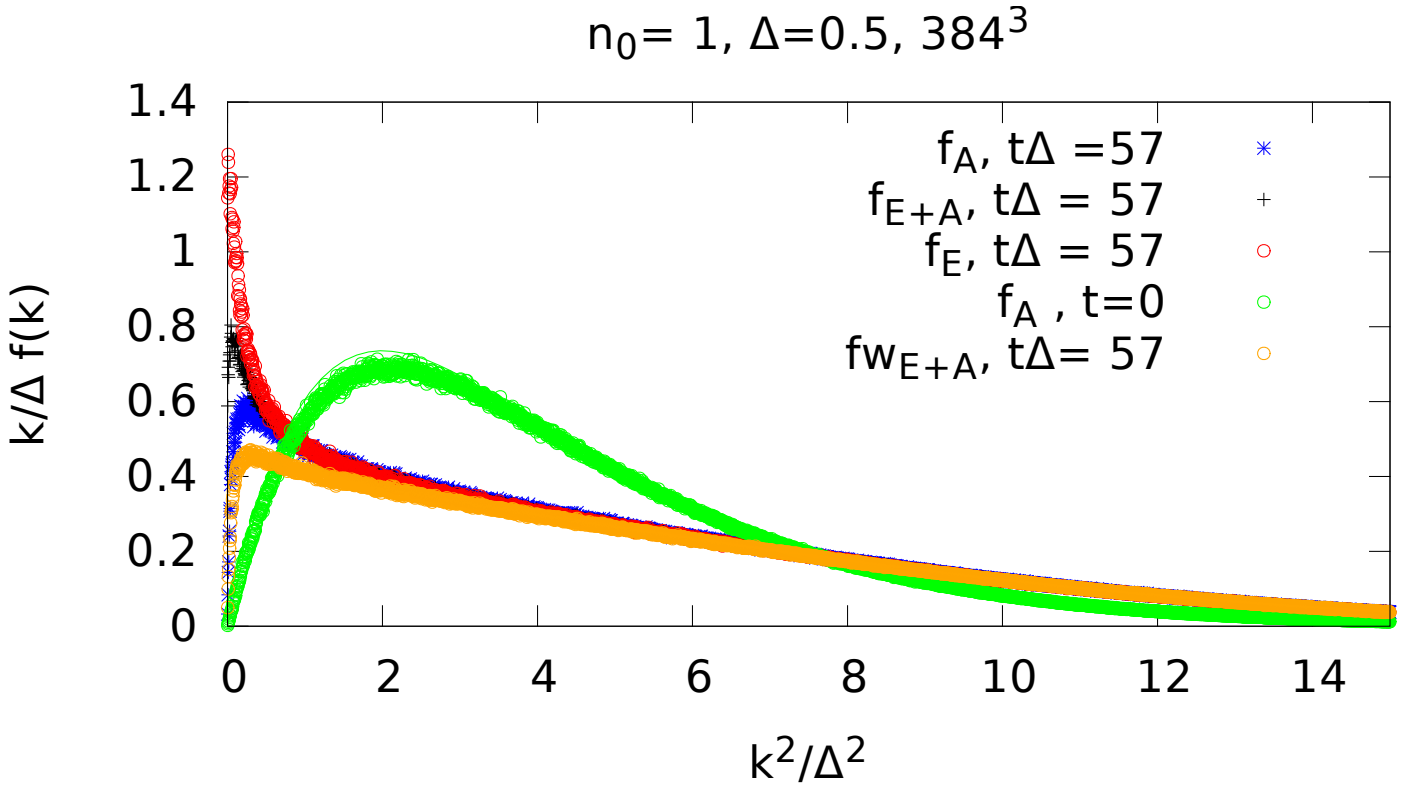
- The HTL formula, however, seems to be sensitive to UV cut-off.



Conclusions

- We have studied the plasmon mass in pure glue QCD using
  - HTL expression
  - dispersion relation
  - plasma oscillations
- In 3D, observe a clear mass gap in the dispersion relation. Does not seem to agree with the values obtained by the other methods.
- In 2D we find a lot better agreement.
- Next steps: Putting HTL-formula and dispersion relation together, check sensitivity for gauge fixing precision, magnetic scale?

Time-evolution (3D,UV)



Uniform electric field (3D)